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ABSORPTION OF BIPHENYL FROM BIPHENYL-TREATED CARTONS BY CITRUS FRUITS AND ITS EFFECT ON DECAY, 1953-54

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Introduction

At the request of the California Section of the Citrus Industry Committee on Fungistats, citrus fruits commercially packed in biphenyl-treated cartons were studied in 1953-54. The study was made by the Quality Maintenance and Improvement Laboratory, Pomona, Calif., and the Fruit and Vegetable Products Laboratory, Pasadena, Calif., of the U. S. Department of Agriculture. The purpose was to determine absorption of biphenyl and its effect on appearance and decay (blue or green mold). The tests were divided into three series as follows:

1. Simulated transit tests in which packed oranges, lemons, and grapefruit, were stored for 2 weeks at transit temperatures of 42° - 44°, 60° - 62°, 72° - 73°, and 87° - 88° F., respectively. These were followed by 2 weeks at a marketing temperature of 72° - 73° to determine the effects of biphenyl on decay, the appearance of the fruit, and the amount of biphenyl absorbed by the fruit.

2. Storage tests with oranges in cartons treated with different amounts of biphenyl to determine the minimum amount of this chemical required to reduce decay and the effects of the different amounts of biphenyl on the amount absorbed by the fruit at several temperatures.

3. Shipping tests from Porterville, California, to New York, N. Y., with oranges packed in vented and nonvented cartons treated with biphenyl to determine the amounts of biphenyl absorbed by the fruit under actual shipping conditions.

Materials and Methods

All the fruit used was first-grade and was processed, handled, and packed by usual commercial procedures except when inoculation of the fruit or deviations from the regular biphenyl applications were necessary.

The carton used for lemons, grapefruit, and oranges was the half-box size. These cartons are strengthened by a collar made of regular (about 7/32 inch thick) corrugated fiberboard (10 by 56 inches) which is folded and inserted so as to add thickness to the sides and ends. The inside dimensions of the cartons with collars are 9 3/4" to 10" high x 11" wide by 16 3/8 to 16 3/4" long.

The usual biphenyl treatment consisted of treating the collars with biphenyl at the rate of 4 pounds to 1000 square feet of collar, except where different amounts of biphenyl were compared. The biphenyl applied to the collars was a proprietary compound containing 50 percent biphenyl. It was applied to only one side of the collar.

The packed fruit used in the simulated-transit tests and in the tests of different amounts of biphenyl was stored in the experimental storage rooms at the Quality Maintenance and Improvement Laboratory at Pomona, Calif. The temperatures of these rooms were 42° - 44°, 60° - 62°, 72° - 73°, and 87° - 88° F., respectively. These were approximately the temperature ranges of 40° - 45°, 60° - 65°, 70° - 75° and 85° - 90° recommended by the Committee. The relative humidity was about 85 - 87 percent in the first three rooms and 78 - 80 percent in the fourth.

Inspections of the fruit in the simulated-transit tests for appearance, condition of the buttons, and decay were made. Samples were inspected when the cartons were put in the storage rooms, on removal after 2 weeks that simulated the transit period, and after 2 more weeks at 72° - 73° that simulated the marketing period. Inspections of fruit in the tests of different amounts of biphenyl to determine the percentage of decay were made after 19 or 20 days in storage at several temperatures.

Chemical analyses for absorption of biphenyl were made on sample cartons at the following 3 times: on removal at the end of the 2- and 4-week storage periods in the simulated-transit tests, after 19 or 20 days in the tests of different amounts of biphenyl, and after arrival at New York in the shipping tests. In each case the sample cartons were sent unopened to the Fruit and Vegetable Products Laboratory at Pasadena, Calif., where the analyses were made. Those from the shipping tests were sent from New York to Pasadena by railway express.

The condition of the buttons was recorded at each inspection of the fruit from the simulated-transit tests. Previous investigations with lemons 1/ had shown that the rate of change of button color from green to black indicates the rate of physiological changes that lead to increased susceptibility to decay caused by Alternaria. The classification of the buttons used in this and previous studies was green; intergreen; interblack; black, and off.

Further details on materials and methods are given in the descriptions of the individual tests.

Effect of biphenyl-treated cartons on decay and appearance of fruit in simulated-transit tests

In two tests each with Valencia oranges, lemons, and grapefruit, biphenyl-treated and untreated cartons were compared for their effects on general appearance of the fruit, condition of the buttons, and decay. Thirty-six cartons of Valencia oranges and 24 cartons of lemons and grapefruit were used for each test. Half the cartons in each test were treated with biphenyl, and half were untreated. Six treated and 6 untreated cartons were stored for 2 weeks at each simulated-transit temperature (3 for oranges and 3 for lemons and grapefruit). At the end of the 2-week period, 2 untreated cartons and 3

1/ Harvey, E. M. Changes in lemons during storage as affected by air circulation and ventilation. U. S. Department of Agriculture, Tech. Bul. 908, 32 pp. 1946.

treated cartons were removed from each temperature, and the others were transferred to the 72° - 73° F. room for another 2-week period.

One of the treated cartons from each temperature was sent unopened to the Fruit and Vegetable Products Laboratory at Pasadena for biphenyl analyses of the fruit, and the fruit in the others was examined to determine its condition. At the end of the 2 weeks at 72° - 73°, fruit in the remaining cartons was examined for condition and analyzed for biphenyl. Also, in one test liquid-waxed and slab-waxed Washington Navel oranges in biphenyl-treated cartons were compared.

The Washington Navel oranges were handled in the same way as the Valencias except that all cartons were treated with biphenyl. Twenty-four cartons of fruit treated with liquid wax and 24 treated with slab wax were used; eight of each were stored at each of the three simulated-transit temperatures. The dates of the tests are given in the tables.

The simulated-transit and market temperatures for the different kinds of fruit are indicated in table 1. The simulated transit temperatures were selected as representative of the temperatures encountered by citrus fruits in transit. For oranges, the 42° - 44° F. temperature was selected to represent transit temperatures of fruit that is precooled before loading and receives good refrigeration in transit. The 72° - 73° temperature was selected as representative of the usual temperature with non-precooled fruit with poor refrigeration, conditions under which many oranges in cartons are shipped. The 87° - 88° temperature was selected to represent the extreme conditions under which non-precooled oranges in cartons are sometimes shipped. For lemons the 42° - 44° and 60° - 62° temperatures were selected as representative of the coolest and of moderate conditions, respectively, during shipment of lemons loaded out of refrigerated storage. The 72° - 73° temperature was selected as representative of the common transit temperature for non-precooled grapefruit, and 87° - 88° as representative of extreme conditions.

Oranges

The Valencia oranges used in the tests for comparing treated and untreated cartons were size 252. Those for the first test were picked June 26 and those for the second September 13. All were from the LaVerne district. They received the commonly used soap-borax-boric acid wash, were gassed for 36 hours with ethylene and then were waxed. The fruit had good color except for considerable green at the stem ends. The buttons were mostly intergreen rather than green.

At the end of the 2-week simulated transit period, the least change in condition of the buttons and least decay in the Valencia oranges had occurred in the fruit at 42° - 44° F. (table 2). The percentage of fruit with black buttons increased in most lots during the next 2 weeks at 72° - 73°. In the second test, there were, in general, a larger percentage of oranges with black buttons in the biphenyl-treated cartons than in the untreated cartons. Differences in decay in the 2 kinds of cartons were not conclusive, but in the first test there was less at the end of 4 weeks in the biphenyl-treated cartons than in the untreated cartons initially held at 42° - 44° and 72° - 73°. At the end of 4 weeks the oranges in all lots in the first test were pliable and had a rather poor general appearance.

Table 1.--Prestorage treatment and simulated-transit and-market storage periods and temperatures for oranges, lemons and grapefruit in simulated transit tests.

Kind of fruit	Prestorage treatment	Temperature (°F) during-	
		simulated-transit period	simulated-marketing period
Orange	Precooling to 42 - 44 (°F)	42 - 44	72 - 73
	No precooling	72 - 73	72 - 73
		87 - 88	72 - 73
Lemon	Holding in warehouse at 60 - 62 (°F)	42 - 44	72 - 73
		60 - 62	72 - 73
Grapefruit	No precooling	72 - 73	72 - 73
		87 - 88	72 - 73

Table 2.--Condition of buttons and amount of decay of Valencia oranges packed in biphenyl-treated cartons and untreated cartons in simulated-transit tests.

Date of inspection	Storage period prior to inspection	Temperature range during storage period	Buttons off		Buttons green		Buttons intergreen		Buttons interblack		Buttons black		Decay in	
			Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit
	weeks	°F.	percent		percent		percent		percent		percent		percent	
First test														
June 30	0 1/	-	25		1		66		8		0		0	
July 13	2	42 - 44	32	31	0	0	11	19	46	43	11	6	0	0
July 27	(2	42 - 44)	23	15	0	0	0	0	1	0	71	72	5	14
	(2	72 - 73)												
July 13	2	72 - 73	24	26	0	0	2	3	6	4	65	63	3	5
July 27	2	72 - 73	25	18	0	0	0	0	1	2	68	65	6	16
July 13	2	87 - 88	26	23	0	0	0	0	2	0	71	74	2	2
July 27	(2	87 - 88)	33	23	0	0	0	1	1	1	63	73	4	2
	(2	72 - 73)												
Second test														
September 15	0 1/	-	16		18		64		2		0		0	
September 29	2	42 - 44	37	24	0	4	14	23	42	37	8	11	0	1
October 13	(2	42 - 44)	14	14	0	0	4	7	17	25	64	52	2	2
	(2	72 - 73)												
September 29	2	72 - 73	33	15	1	3	6	15	13	30	47	35	1	2
October 13	4	72 - 73	15	24	0	0	1	4	9	15	69	52	7	5
September 29	2	87 - 88	37	13	0	2	2	9	5	32	57	42	0	2
October 13	(2	87 - 88)	20	16	0	2	0	13	0	12	77	51	3	6
	(2	72 - 73)												

1/ Before storage.

This was especially noticeable in the fruit initially held at 87° - 88°. At the end of 4 weeks in the second test the fruit initially held at 72° - 73° and 87° - 88° had a general dull appearance and was soft.

The Washington Navel oranges used in the tests for comparing liquid-waxed and slab-waxed fruit in biphenyl treated cartons were size 200 and were from the Riverside district. The liquid-waxed oranges were picked January 22, and received the soap-wax-boric acid wash. Their general appearance was very good and all buttons were green (79 percent full green). The slab-waxed oranges were picked January 27. They received a washing treatment in a detergent solution at 120° F. Their general appearance was good. The buttons were mostly green, but seven were off and there were a considerable number in the intergreen class. Neither lot of Washington Navel oranges was gassed with ethylene.

At the end of the 2-week simulated-transit period (table 3), the least change in condition of the buttons had occurred in the oranges at 42° - 44° F. At the end of 4 weeks there were considerably more slab-waxed oranges with black buttons than liquid-waxed in the lots initially held at 72° - 73° and 87° - 88°. Differences in decay were not consistent.

At the end of the 2-week simulated-transit period both the liquid-waxed and the slab-waxed fruit had a very good general appearance, but the fruit that had been at 42° - 44° and 72° - 73° had considerable stickiness at the surface. The liquid-waxed fruit at those temperatures also felt and appeared moist, especially the oranges that had been at 42° - 44°. The oranges that had been at 87° - 88° were dry and free of stickiness and were not noticeably shrunken.

After 4 weeks the liquid-waxed oranges still had a generally good appearance and were firm and bright. The oranges held at 87° - 88° had a lighter color and were a little soft. After 4 weeks the slab-waxed oranges initially at 42 - 44° had good color but were somewhat pliable. Those held the entire time at 72° - 73° had a poor appearance and showed considerable aging (9 - 17%). Those initially at 87° - 88° were badly softened, had poor color and appearance, and showed considerable aging (19%). It is uncertain whether these differences were due to the treatments, to the more advanced aging of the buttons in the slab-waxed lot at the beginning of the test, or to differences in the washing treatments.

Lemons

The lemons used in the first test were size 252-300. They were picked June 17, and were firm and of good appearance. There was considerable green sheen to the fruit surface, giving the general appearance of very good "silvers", but they lacked stronger green color around the stylar end. They had been treated with nitrogen trichloride gas. The lemons used in the second tests were picked August 31, and were about the equivalent of "light greens" when packed. They had been gassed with ethylene and nitrogen trichloride. Lemons for both tests were of the Eureka variety from the Corona district. They were washed with soap soda ash followed by 2,4-D in water wax.

Table 3.--Condition of buttons and amount of decay of Washington Navel oranges treated with liquid wax and slab wax and packed in biphenyl-treated cartons in simulated-transit tests.

Date of inspection	Storage prior to inspection	Temperature range during storage	Buttons off		Buttons green		Buttons intergreen		Buttons interblack		Buttons black		Decay in	
			L 1/	S 2/	L	S	L	S	L	S	L	S	L	S
	weeks	°F.	percent		percent		percent		percent		percent		percent	
January 26 and 29	Before storage	-	2	7	79	62	19	30	0	1	0	0	0	0
February 9 and 11	2	42 - 44	2	8	61	54	33	35	3	2	0	0	2	1
February 23 and 25	(2	42 - 44	2	6	28	18	21	26	42	42	3	6	3	2
	(2	72 - 73												
February 9 and 11	2	72 - 73	2	11	32	22	28	24	34	36	2	3	3	4
February 23 and 25	4	72 - 73	2	10	24	2	19	21	41	23	6	38	7	5
February 9 and 11	2	87 - 88	5	8	35	21	25	25	32	38	2	7	1	1
February 23 and 25	(2	87 - 88	5	5	22	4	32	25	34	32	2	28	4	5
	(2	72 - 73												

1/ L - Liquid-waxed fruit
2/ S - Slab-waxed fruit

Decay of lemons was unimportant in both tests (table 4). In the first test the buttons on fruit in the treated cartons were somewhat darker, but the change in color was not as great as in the Valencia oranges. The change was slightly greater in the fruit initially stored at 42° - 44° F. after subsequent storage at 72° - 73° than after the first 2 weeks at the lower temperature. The general appearance of the fruit in both tests was good after 4 weeks, and the lemons were still firm. In the first test, lemons initially held at 60° - 62° showed less green than those at 42° - 44°, and in the second test fruit in all lots showed some overcolor and some were distinctly reddish.

Grapefruit

The grapefruit used in the first test were size 126 and were picked July 1. They were smooth and firm, showed considerable even green sheen to patchy green, and had a very good general appearance. The grapefruit used in the second test were size 100, and were picked in the same district September 17. These fruit were somewhat pliable but had considerable green sheen in background color and a very good general appearance. The grapefruit used in both tests were of the Marsh variety from the Riverdale district.

Decay of grapefruit was negligible in both tests (table 5), but it was somewhat higher in fruit in the untreated cartons. Except in one instance, it was higher after the 2-week simulated-marketing period at 72° - 73° F. than after the first 2 weeks at 72° - 73° or 87° - 88°. Changes in color were variable, but the greatest change occurred in the fruit in the treated cartons. Change in button color was more rapid in the fruit initially stored at 72° - 73° than in fruit stored at 87° - 88°. In both tests the fruit was firm and had a good general appearance at the end of the first 2 weeks. That stored at 87° - 88° in the second test was yellow but somewhat overcolored. Fruit in the first test still had a good general appearance after 4 weeks, but the general appearance of the fruit in the second test was rather poor, and it showed considerable reddish overcolor and softness. Also, in the second test fruit held initially at 72° - 73° in biphenyl-treated cartons showed a great deal of surface stickiness, but fruit in both kinds of cartons stored at 87° - 88° did not.

Effects of different amounts of biphenyl in the carton on decay of Valencia oranges stored at several temperatures

Before the oranges were packed a scratch about 1 mm. deep and 10 mm. long (tests 1 and 2) and about .75 mm. deep and 10 mm. long (test 3) was made across the shoulder near the stem end of each. After being scratched the fruit for the first test was inoculated by submerging for 5 minutes in a water suspension of spores of the fungi that cause blue and green molds. In the other two tests dry spores of those fungi were fed into the air currents of two electric fans directed toward the fruits.

The collars for the cartons were treated with 4 pounds of biphenyl[2/] per 1000 square feet of collar, the usual commercial rates, and with 2, 1, 1/2 and 0 pounds to determine the effectiveness of less than the usual amounts. For the

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2/ Equals 8 pounds of proprietary compound containing 50 percent biphenyl.

Table 4.--Condition of buttons and amount of decay of lemons packed in biphenyl-treated cartons and untreated cartons in simulated-transit tests.

Date of inspection	Storage period prior to inspection	Temperature range during storage period	Buttons off		Buttons green		Buttons intergreen		Buttons interblack		Buttons black		Decay in	
			Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit
	weeks	°F.	percent		percent		percent		percent		percent		percent	
First test														
June 30	0[1]	-	15		53		30		3		0		0	
July 14	2	42 - 44	14	12	26	33	53	48	7	6	0	0	0	0
July 28	(2	42 - 44)	9	2	32	49	31	28	23	18	4	3	1	0
	(2	72 - 73)												
July 14	2	60 - 62	17	14	26	43	37	30	20	12	1	1	0	0
July 28	(2	60 - 62)	19	0	26	44	27	28	24	22	4	5	1	0
	(2	72 - 73)												
Second test														
September 17	0[1]	-	0		50		30		19		1		0	
October 1	2	42 - 44	2	2	52	51	26	20	17	21	3	6	0	0
October 15	(2	42 - 44)	2	1	49	53	28	27	18	15	3	2	0	2
	(2	72 - 73)												
October 1	2	60 - 62	1	2	54	54	27	24	16	17	2	3	0	0
October 15	(2	60 - 62)	0	1	44	52	29	29	22	16	5	0	0	1
	(2	72 - 73)												

1/ Before storage.

Table 5.--Condition of buttons and amount of decay of grapefruit packed in biphenyl-treated cartons and untreated cartons in simulated-transit tests.

Date of inspection	Storage period prior to inspection	Temperature range during storage period	Buttons off		Buttons green		Buttons intergreen		Buttons interblack		Buttons black		Decay in	
			Treated fruit	Check fruit	Treated Fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit	Treated fruit	Check fruit
	weeks	°F.	percent		percent		percent		percent		percent		percent	
First test														
July 2	0 1/	-	16		22		59		3		0		0	
July 15	2	72 - 73	18	12	0	4	13	32	44	37	24	12	0	4
July 28	4	72 - 73	11	12	0	0	1	2	3	9	85	69	1	8
July 15	2	87 - 88	23	5	0	3	0	14	8	22	69	54	0	3
July 28	(2	87 - 88)	28	10	0	0	0	5	1	5	71	79	1	1
	(2	72 - 73)												
Second test														
September 18	0 1/	-	54		25		19		2		0		0	
September 29	2	72 - 73	51	55	0	5	5	11	18	21	23	8	2	0
October 15	4	72 - 73	46	55	0	0	0	1	1	0	51	37	2	7
September 29	2	87 - 88	53	61	0	0	1	2	1	6	43	30	2	1
October 15	(2	87 - 88)	58	50	0	0	0	2	0	1	37	39	5	8
	(2	72 - 73)												

1/ Before storage.

first test commercially prepared collars containing 4, 2, 1, and 0 pounds of biphenyl were used. Collars containing 1/2 pound were prepared at the laboratory by using a proportional part of a commercially treated collar. For the last two tests the 2-, 1-, and 1/2 pound liners were prepared by using proportional parts of commercially treated collars.

In the first test, five cartons of size 252 Valencia oranges were used for each amount of biphenyl. They were stored at 72° - 73° F. the morning after they were inoculated. A tentative inspection 6 days later showed that nearly 100 percent of the oranges were already affected with decay, and the test was discontinued although it had been expected to run for 4 weeks. At this time blue and green molds had advanced about 1/3 through the fruit in the cartons treated with 4 and 2 pounds of biphenyl and about 3/4 through the fruit in the cartons containing less or no biphenyl. Also, the advancing nonsporulating zones of the blue and green molds were wider, and there were a few more sound oranges in the 4- and 2-pound treated cartons than in the others.

Three cartons of size 200 Valencia oranges were used for each amount of biphenyl in the second test, and the same number of cartons of size 200 liquid-waxed Washington Navel oranges were used in the third test. Immediately after inoculation of the fruit, the cartons in the second test were stored at 42° - 44° F. for 7 days, and then successively at 60° - 62° for 7 days, and at 72° - 73° for 5 days. Some mold was present on fruit in the untreated cartons after 7 days at 42° - 44° and considerable mold on fruit in all lots after 7 days at 60° - 62°. The cartons in the third test were stored for 12 days at 60° - 62°, immediately after inoculation of the fruit, and then for 8 days at 72° - 73°.

The percentages of fruit decayed in the second and third tests at the end of the storage period are shown in table 6. These values indicated that the effectiveness of biphenyl is much reduced when less than about 2 pounds is present in 1000 square feet of collar. Best control of decay was obtained with the 4-pound rate. The amount now used in commercially treated cartons is close to the minimum that can be recommended.

Absorption of biphenyl at various transit and marketing temperatures

The data on absorption obtained from analysis of oranges from the simulated-transit and marketing tests (table 7) indicate that the amount of biphenyl absorbed by the fruit in general increased as the transit temperature increased. The peel absorbed much more biphenyl than the juice. The amount of biphenyl absorbed increased during the 2-week simulated-marketing period at 72° - 73°. Lemons absorbed less biphenyl than either oranges or grapefruit.

The tests with different amounts of biphenyl (table 8) showed that the amounts of biphenyl absorbed by the fruit increased as the amount of biphenyl in the cartons increased. The biggest differences occurred between the fruit from

Table 6.--Decay of oranges in cartons treated with various amounts of biphenyl.

Biphenyl[1/] treatment (pounds per 1000 sq. ft. of collar)	Oranges decayed (percent) in- Test 2 [2/]	Test 3 [3/]
4	51	3
2	71	5
1	90	8
1/2	90	20
0	96	43

1/ Proprietary compound (5% biphenyl) applied to one side of collar.
2/ After 7 days at 42°-44° F., 7 days at 60°-62° and 5 days at 72°-73°.
3/ After 12 days at 60°-62° F. and 8 days at 72°-73°.

Table 7.--Biphenyl absorbed by citrus fruits packed in treated cartons during 2-week simulated transit period and in a 2-week simulated marketing period.

Kind of fruit, test no. and date	Temperature during transit period	Biphenyl (p.p.m.) absorbed during transit period by			Temperature during marketing period	Biphenyl (p.p.m.) absorbed during marketing period by		
		Juice	Peel	Whole fruit		Juice	Peel	Whole fruit
	°F				°F			
Valencia oranges (Test 1, June 30 - July 27, 1953)	42 - 43	---	---	---	70	2.43	448.	---
	72 - 73	---	---	---	70	1.21	596.	---
	87 - 88	---	---	---	70	1.80	870.	---
Valencia oranges (Test 2, Sept. 15 - Oct. 13, 1953)	42 - 43	0.50	73.7	---	70	2.79	420.	---
	72 - 73	2.2	378.0	---	70	3.39	445.	---
	87 - 88	3.54	576.0	---	70	3.89	544.	---
Flavorseal-waxed Washington Navel oranges (Test 3, Jan.26-Feb.23,1953)	42 - 43	0.53	119.0	33.1	70	0.91	187.2	80.6
	72 - 73	0.90	180.2	53.8	70	1.44	320.2	131.9
	87 - 88	0.73	307.4	74.7	70	0.50	355.6	132.8
Slab-waxed Washington Navel oranges (Test 4, Jan. 29-Feb.26,1954)	42 - 43	0.55	107.1	30.1	70	0.77	426.8	103.9
	72 - 73	1.97	291.9	93.7	70	2.10	405.8	94.7
	87 - 88	0.78	328.8	80.8	70	0.76	281.8	78.4
Lemons (Test 5, June 30 - July 28, 1953)	42 - 43	---	---	---	70	0.74	62.4	---
	60 - 62				70	1.06	234.0	---
Lemons (Test 6, Sept. 17 - Oct. 15, 1953)	42 - 43	0.19	13.8	---	70	1.83	142.0	---
	60 - 62	0.25	26.9	---	70	0.53	78.5	---
Grapefruit (Test 7, July 2-July 28,1953)	72 - 73	---	---	---	70	4.95	481.0	---
	87 - 88	---	---	---	70	6.93	509.0	---
Grapefruit (Test 8, Sept.18-Oct.14,1953)	72 - 73	1.29	156.	---	70	2.30	181.0	---
	87 - 88	3.22	288.	---	70	4.41	496.	---

Table 8.--Biphenyl absorbed oranges from cartons treated with different amounts of biphenyl

Kind of orange and date of test	Time at each temperature (°F.) in storage	Biphenyl treatment (pounds per 1000 sq.ft.)	Biphenyl (gm.) per collar		Biphenyl (p.p.m.) absorbed by fruit		
			Estimated	Actual	Juice	Peel	Whole
Valencia							
Aug. 3-9, 1953	6 days at 72 - 73	(1/2	1.05	0.88	---	---	32.3
		(4	8.4	8.8	---	---	71.7
Washington Navel:							
Oct. 2-21, 1953	7 days at 42 - 43 plus 7 days at 60 - 62 plus 5 days at 72 - 73	(1/2	1.05	---	---	17.5	---
		(1	2.1	---	0.17	24.6	---
		(2	4.2	---	0.59	124.0	---
		(4	8.4	---	0.57	108.0	---
Mar. 5-25, 1954	12 days at 60 - 62 plus 8 days at 72 - 73	(1/2	---	---	0.59	93.5	---
		(1	---	---	0.81	137.2	---
		(2	---	---	1.50	222.8	---
		(4	---	---	1.84	327.8	---

cartons treated at the 1- and 2-pound rates. This was in agreement with the relation of decay to amount of biphenyl in the cartons, in which the biggest differences in decay control occurred at about this point.

The shipping tests to New York (table 9) did not show as clear a relation of absorption to temperature as the simulated-transit tests, probably because of the small differences in temperature of the boxes in the different positions in the cars. In these tests oranges from the vented cartons generally contained less biphenyl than those from the nonvented cartons. Decay was negligible.

Summary and Conclusions

The effects of biphenyl-treated cartons on decay, the general appearance of citrus fruits packed in them, and the amounts of biphenyl absorbed by the fruits at various transit and marketing temperatures were studied.

Cartons fitted with collars treated at the usual commercial rate of 4 pounds of biphenyl to 1000 square feet of collar surface reduced decay somewhat in tests with oranges and grapefruit. However, the results were not consistent enough to be conclusive. Decay was unimportant in the tests with lemons. In general, there was more darkening of buttons of fruit packed in treated cartons. A transit temperature of 42° - 44° F. retarded darkening of the buttons, but darkening took place rapidly after the cartons of fruit were transferred to 72° - 73°.

Data from tests with oranges in cartons treated with 4-, 2-, 1-, 1/2-, and 0-pounds of biphenyl per 1000 square feet indicated that the treatment was less effective in reducing decay when less than about 2 pounds was used. Best control was obtained with the 4-pound rate. These results indicate that the amount now used in commercially treated cartons is close to the practical minimum that can be recommended.

Analysis of oranges from all of the tests showed that considerable biphenyl is absorbed from the cartons by the juice and the peel. The amount of biphenyl absorbed was greater at the higher temperatures than at the lower temperatures and the amount absorbed increased during the 2-week simulated marketing period at 70° - 72° F. Lemons absorbed less biphenyl than oranges and grapefruit in these tests. Oranges absorbed more biphenyl from cartons treated at the higher rates. The biggest differences occurred between the fruit from cartons treated at the 1- and the 2-pound rates. Oranges in nonvented cartons absorbed more biphenyl than those in vented cartons.

Table 9.--Biphenyl absorbed by Washington Navel oranges from treated vented and nonvented cartons while in transit from Porterville, California, to New York and return, 1953.

Car and date of loading	Average transit temperature 1/	Position in car	Type of carton	Biphenyl (p.p.m.) absorbed by		
				Juice	Peel	Whole fruit
	°F					
Car A (Dec. 7)	55	Middle quarter center line	nonvented	0.77	89.0	21.1
			vented	0.81	103.4	34.6
	49	Middle quarter wall	nonvented	0.66	80.8	30.0
			vented	0.81	109.5	33.6
Car B (Dec. 7)	58	Middle quarter center line	nonvented	0.80	97.7	38.2
			vented	0.69	92.7	28.8
	51	Middle quarter wall	nonvented	1.37	162.5	44.8
			vented	0.42	63.9	22.2
Car C (Dec. 8)	58	Middle quarter center line	nonvented	1.62	206.3	52.3
			vented	1.09	193.1	55.9
	54	Middle quarter wall	nonvented	(no collar in carton)		
			vented	1.26	177.0	42.2
Car D (Dec. 11)	56	Middle quarter center line	nonvented	1.39	191.4	52.8
			vented	1.08	160.6	50.8
	51	Middle quarter wall	nonvented	1.37	203.0	50.8
			vented	0.62	98.2	32.0
Car E (Dec. 1)	57	Middle quarter center line	nonvented	1.47	183.1	63.9
			vented	1.00	136.6	46.2
	55	Middle quarter wall	nonvented	1.59	190.9	61.3
			vented	0.74	110.6	39.3

1/ Temperatures obtained by recording thermographs placed in vented cartons.